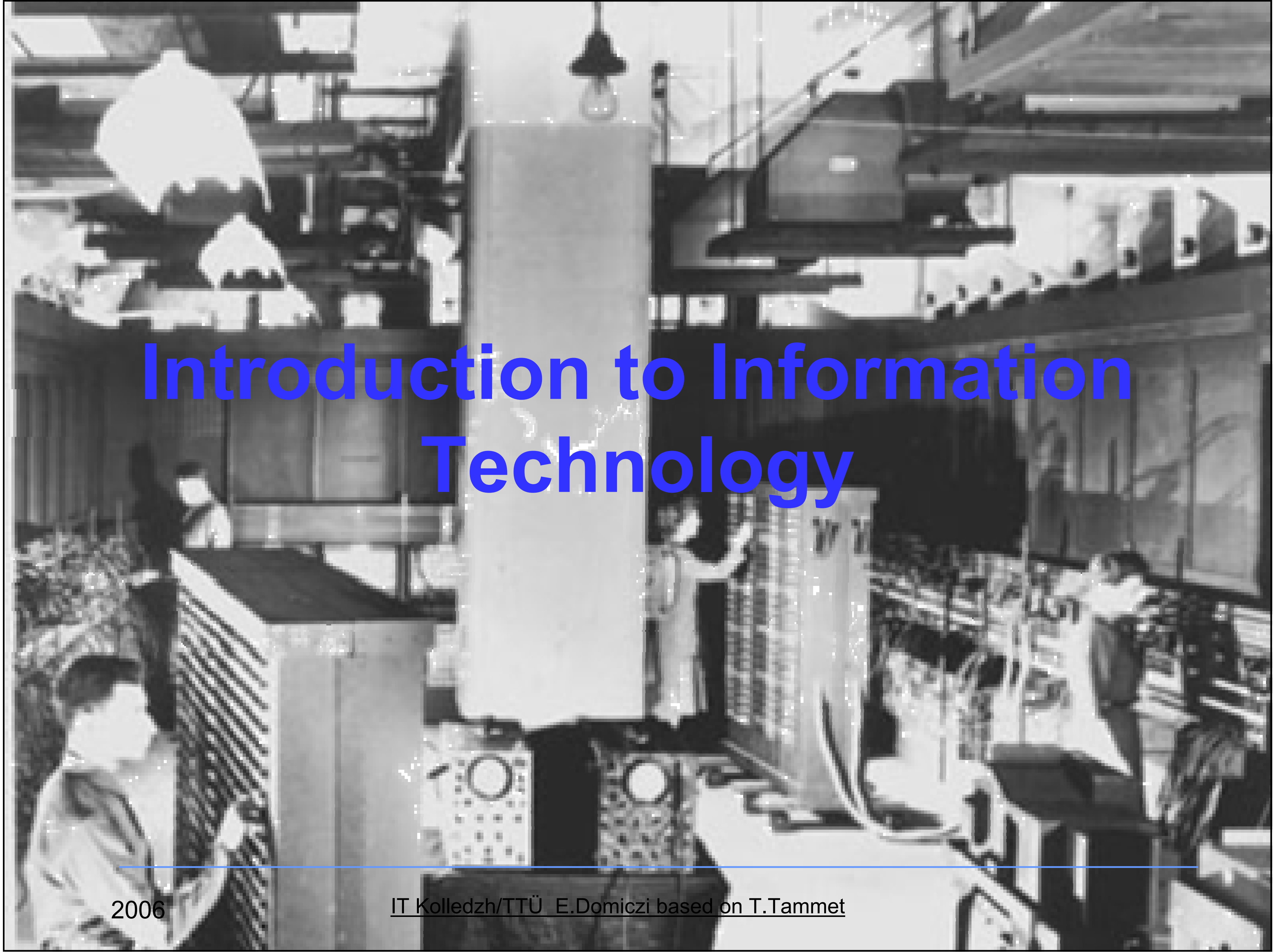


Introduction to Information Technology

Lecture overview

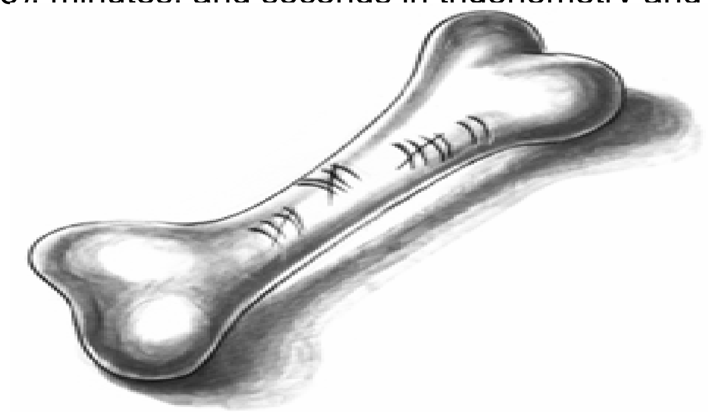
The birth of computers and computer science:
from the beginning of time - WWII.

- **Early history of figuring**
- **Origins of logic**
- **Origins of computing theory**
- **First computers in the XVII. (17th) century**
- **Ideology of industrialization**
- **Enabling technology: communication and mechanical information processing**
- **Development of logic and computing theory in the first half of the XX. (20th) century**
- **The first powerful computers in WWII**

Numbers

Numbers with bones:

- **period 20,000 - 30,000 years back Cro-Magnon appears**
- **Babylonian sexagesimal(base-sixty) numeral system**
  - **the first known place-value numeral system**
  - first appeared around 1900 BC to 1800 BC
  - survive to this day, in the form of degrees (360° in a circle), minutes, and seconds in trigonometry and the measurement of time.
- Maya numeral system
  - vigesimal (base-twenty) numeral system.



Null:

- **Babylonia 300 BC**
  - The lack of a positional value (or zero) was indicated by
    - a space between sexagesimal numerals.
    - By 300 BC a punctuation symbol (two slanted wedges) was co-opted as a placeholder in the same Babylonian system
- **India 600 AD**

Abacus:

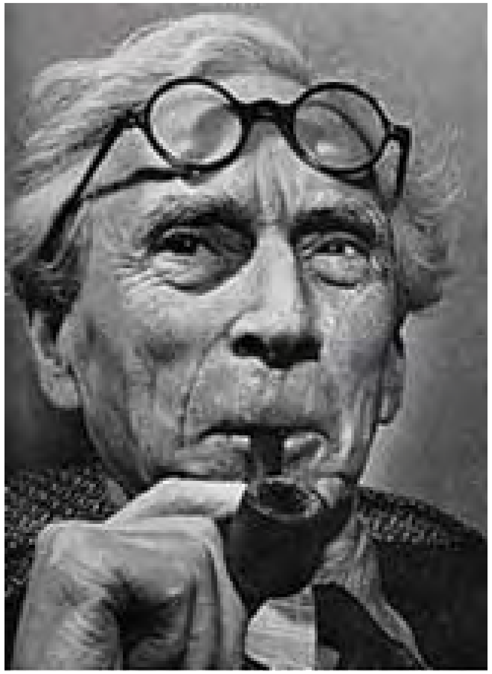
- **a calculation tool, often constructed as a wooden frame with beads sliding on wires**
- **Babylonia 1,000 BC - 500 BC**

Great Logicians: Russell (1872-1970)

- Russell's contributions to logic and the foundations of mathematics include
  - his discovery of Russell's paradox,
  - his defense of logicism (the view that mathematics is, in some significant sense, reducible to formal logic),
  - his development of the type theory, and his refining of the first-order predicate calculus.
- Russell discovered the paradox that bears his name in 1901:
  - Let M be "the set of all sets that do not contain themselves as members".
    Formally: A is an element of M if and only if A is not an element of A

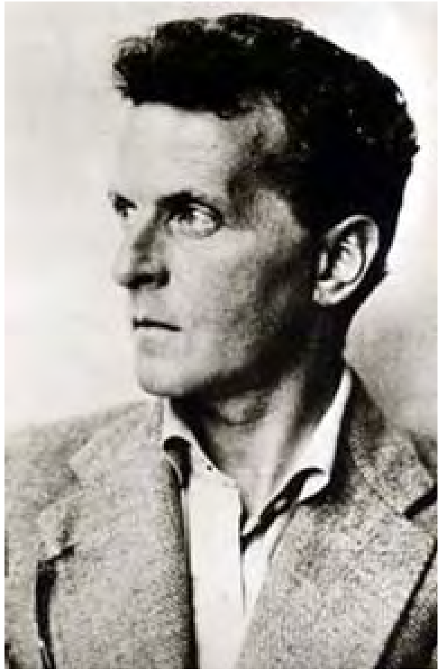
    $$M = \{A \mid A \notin A\}.$$

    If M contains itself, M is not a member of M according to the definition.
    If M does not contain itself, then M has to be a member of M, again by the very definition of M.
    The statements "M is a member of M" and "M is not a member of M" cannot both be true, thus the contradiction
- B.Russell, ”Introduction to Mathematical Philosophy”



Great Logicians: Wittgenstein (1889-1951)

- *L.Wittgenstein, `` **Tractatus Logico-Philosophicus**"*
- Theses of the book:
  - the world consists of independent atomic facts — existing states of affairs — out of which larger facts are built.
  - Language consists of atomic, and then larger-scale propositions that correspond to these facts by sharing the same "logical form."
  - Thought, expressed in language, "pictures" these facts.
  - We can analyse our thoughts and sentences to express ('express' as in *show*, not *say*) their true logical form.
  - Those we cannot so analyse cannot be meaningfully discussed.
  - Philosophy consists of no more than this form of analysis: "*Wovon man nicht sprechen kann, darüber muß man schweigen"* — whereof one cannot speak, thereof one must be silent.



Subject of Logic

Fundamental thinking methods:

- **Deduction**
- **Induction**

Mathematical inputs: variables

Statement variables:

- **``if A and B, then A"**
- **``it is not true, that A and not A"**
- **``if B follows A, so if A is true, then so is B true"**

Properties:

- **"If all matters have property P, then exists a matter, which has the property P"**
- **??? "If there is a matter, which has property P, then all matters have property P"**

Origins of Logic

- **Parmenides (5th centrury B.C.) :**
  makes the ontological argumenent against nothingness, essentially denying the possible existence of a void.
- **Zenon from Elea (born about 488 B.C)**
  at the age of forty accompanied Parmenides to Athens. - aporia/paradox
  - Aporia: means just that: No way out (deadlock).
    Greek: ἀπορία: *impasse*; *lack of resources*; *puzzlement*
  - Paradox: (Gk: παράδοξος, "aside belief") is
    an apparently true statement or group of statements that
    leads to a contradiction or
    a situation which defies intuition.
  - "a wanderer that walk half of the way to the goal everyday will never reach it"
    riddle turtle vs Ascilleus:
  - the best runner in the antique world Ascilleus (Achilles) are running against a turtle. The turtle starts 10 meter in front of Ascilleus and Ascilleus running speed are 10x the speed of the turtle. The question is: when is Ascilleus reaching the turtle?
  - the answer is: NEVER!
  - It seemed pretty logical when you saw the explanation.
    When ascilleus has run the 10 meter the turtle was 1 m in front of him.
    he's 10 cm in front of Ascilleus when Ascilleus has run the next meter etc.
    but there's still something wrong about it.
    he's always running faster than the turtle, but he will never reach it.

Origins of Logic

- **Sophists - Sokrates (470-399 BC)**
  - Sophism (gr. sophistes meaning "wise-ist," or one who 'does' wisdom, i.e. who makes a business out of wisdom; cf. sophós, "wise man", cf. also wizard) was originally a term for the techniques taught by a highly respected group of philosophy and rhetoric teachers in ancient Greece.
  - Today, a sophism generally refers to a particularly confusing, illogical and/or insincere argument used by someone to make a point. Sophistry refers to the practice of using such arguments, and is used as derogative for rhetoric that is designed to appeal to the listener on grounds other than the strict logical cogency of the statements being made.
  - The Sophists are known today only through the writings of their opponents (specifically Plato and Aristotle), which makes it difficult to formulate a complete view of the Sophists' beliefs. However, modern research has shown that their views were much more complex than Plato's depiction
- **Platon (427 - 347 BC; whose real name is believed to have been *Aristocles*)**
  - Plato's influence has been especially strong in mathematics and the sciences. It inspired the greatest advances in logic since Aristotle
  - 'Things equal to the same thing are equal to each other"

Origins of Logic : Aristoteles

- **A** syllogism **(Greek: συλλογισμός — "conclusion", "inference"), usually the categorical syllogism, is a kind of *logical argument* in which one *proposition* (the conclusion) is *inferred* from two others (the *premises*) of a certain form.**

Examples of syllogisms: :

- **1. premise: every dog is a mammal.**
  2. premise: many four-legged animals are dogs.
  conclusion: many four-legged animals are mammals.

- **1. premise: every anarchist is against the system.**
  2. premise: many politicians are anarchists.
  conclusion: many politicians are agains the system.

The structure of the derivation can be shown with variables x,y and z:

- **1. premise: every x is y.**
  2. premise: many z's are x.
  conclusion: many z's are y.

Aristoteles “Categorical Syllogism/Logical Arguments”

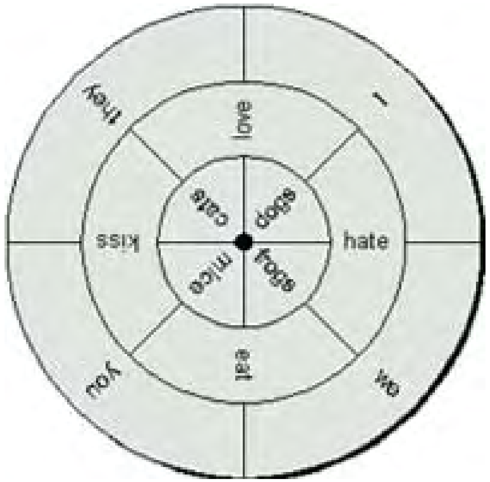
- **``Every b is an a".**
- **``No b is not an a".**
- **``Some b’s are a”.**
- **``Some b’s are not a’s".**

Aristoteles always spoke about 2 categorical premises and 1 categorical conclusion.

- Types of syllogism
- **Although there are infinitely many possible syllogisms, there are only a finite number of logically distinct types. We shall classify and enumerate them below. Note that both the syllogisms above share the same abstract form:**
  - Major premise: All M are P.
  - Minor premise: All S are M.
  - Conclusion: All S are P.
- **The premises and conclusion of a syllogism can be any of four types, which are labelled by letters as follows. In the syllogisms above, only universal affirmatives (A) are used.**
- **The letters standing for the types of proposition (A, E, I, O) have been used since the mediæval Schools to form mnemonic names for the forms. The meaning of the letters is given by the table:**
-
  - A...All Xs are Ys..........universal affirmatives......(e.g., "all humans are mortal")
  - E...No Xs are Ys...........universal negatives.........(e.g., "no humans are perfect")
  - I...Some Xs are Ys.........particular affirmatives.....(e.g., "some humans are healthy")
  - O...Some Xs are not Ys......particular negatives........(e.g., "some humans are not clever")
- According to Copi, p. 127: 'The letter names are presumed to come from the Latin words "*A*ff*I*rmo" and "n*E*g*O*," which mean "I affirm" and "I deny," respectively; the first capitalized letter of each word is for universal, the second for particular'

Ramon L(u)ll (1235-1315)

- **Mysticism**
  Ramon Llull also had a strong mystical side, instantiated in his work The Book of the Lover and His Beloved, written in order to illuminate weary, sterile souls. He was also interested in, and wrote about, astrology.Peateos *Ars magna, generalis et ultima*

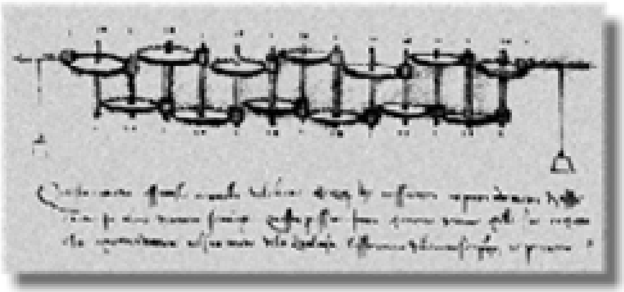


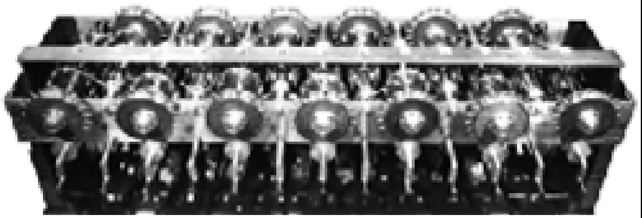
- **Mathematics and statistics**
  with the 2001 discovery of his lost manuscripts Llull is given credit for discovering the Borda count and Condorcet criterion.
- **The terms Llull winner and Llull loser are ideas in contemporary voting systems studies that are named in honor of Llull.**
- **Also, Llull is recognized as pioneer of computation theory, especially due to his great influence on Gottfried Leibniz.**

Leonardo da Vinci (1452-1519)

- **Many references cite the French mathematician, physicist, and theologian,** Blaise Pascal **as being credited with the invention of the first operational calculating machine called the Arithmetic Machine.**

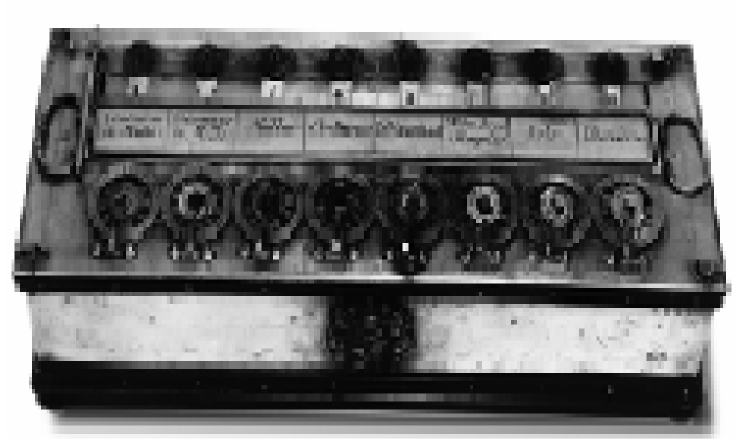
- **It now appears that the first mechanical calculator may have been conceived by Leonardo da Vinci**
  almost 150 years earlier than Pascal's machine
- **Calculator figures**
  - Sketch of Calculator:
  - Working model based on sketch





Schickard & Pascal

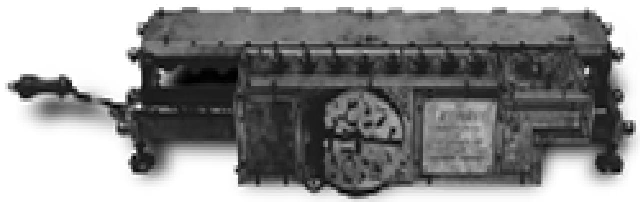
- Schickard 1625:
  adds, subtracts, multiplies, divides
- Blaise Pascal **1640**:
  Arithmetic Machine: only add and subtract

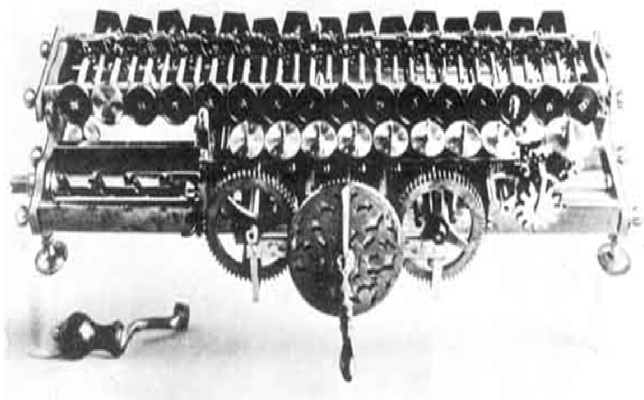


- 50 pieces made

Leibniz

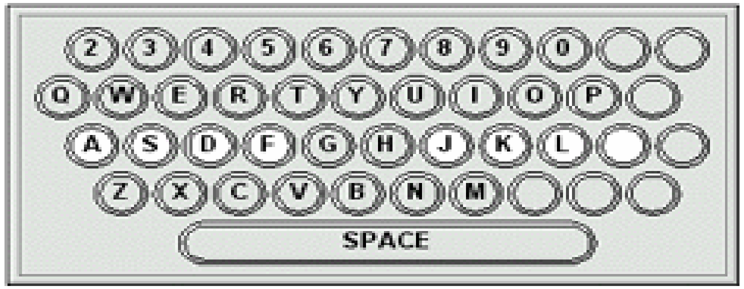
- German Philosopher 1646-1716
- Step Reckoner (1671)
  add, subtract, multiply, divide
  evaluate square roots
- he invented it in his sleep
- The Calculus Ratiocinator is a concept appearing in the writings of Gottfried Leibniz, usually paired with his characteristica universalis, which he mentioned much more frequently.



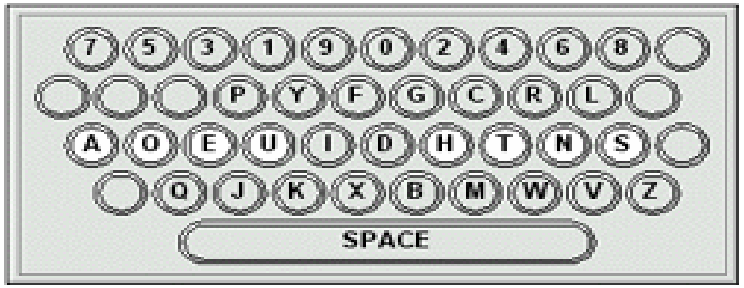


Typing machine

- English patent, Henry Mill, 1714, not built
- **American patent: 1829 William Austin Burt Detroidis**
- **1867, Christopher Latham Sholes, Carlos Glidden, Samual W. Soule creation: “Type-Writer“**
- **Remington: 1874 (with a foot pedal!)**
- **Sholes’ keyboard ca 1874:**

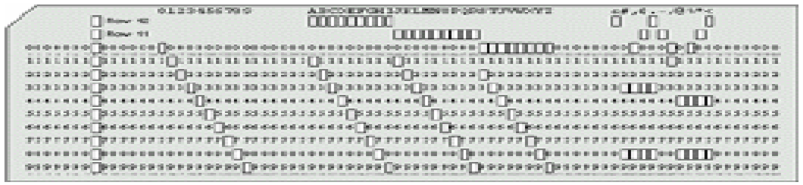


- **Dvorak’s keyboard ca 1936**



Perforated cards / punch cards

- ca 1800, Jacquard
- IBM's perforated card:

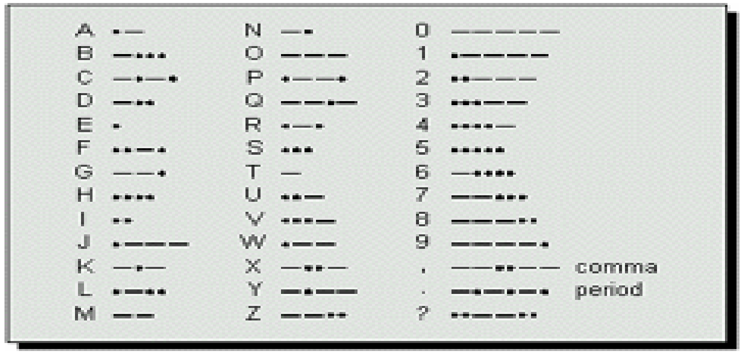


Charles Babbage

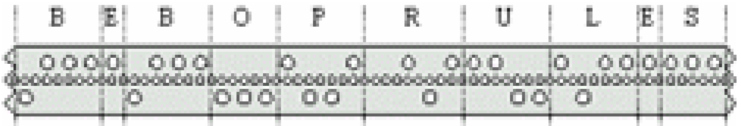
- 1822: Difference Engine, was not finished
- Idea: Analytical Engine
- first programmer: Ada Lovelace

Telegraph

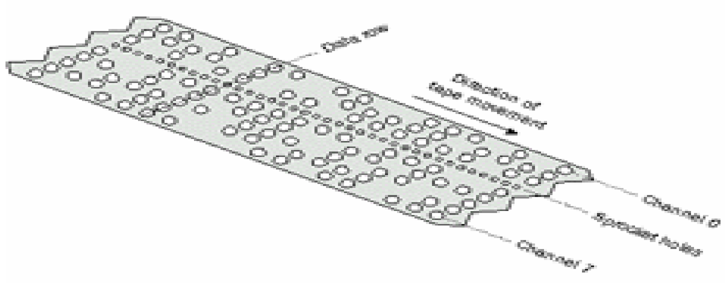
- **Morse 1837:** electrictelegraph



- **Wheatstone 1857:** punch tape for telegraphs



- **Computers' punch tape:**



- **1902-1910: teleprinter**

George Boole, de Morgan

- Basics of Logic 1847-1854
- Using ideas of mathematical algebra to logic:
- Logical algebra:

$$1A = A,\ 0A = 0,\ A+0 = A,\ A+1 = 1$$

$$A+B = B+A,\ AB = BA,\ AA = A$$

Basics of Sentential Calculus

- Logical operations are functions
  with logical/truth-values True and False.

- Mostly used functions are
  - & (AND i.e. conjunction)
  - V (OR i.e. disjunction)
  - \- (NOT)
  - => (implication)
  - == (equivavlence)

A	&	B
T	T	**T**
T	F	**F**
F	F	**T**
F	F	**F**

A	V	B
T	T	**T**
T	T	**F**
F	T	**T**
F	F	**F**

-	A
F	**T**
T	**F**

A	=>	B
T	T	**T**
T	F	**F**
F	T	**T**
F	T	**F**

Basics of Sentential Calculus (2)

- From elementary operations one can compose arbitrary expressions, which realize logical (truth-value) functions

(-	(A	**&**	B))	**=>**	(B	**V**	C)
F	**T**	T	**T**	T	**T**	T	**T**
T	**T**	F	**F**	T	**F**	T	**T**
T	**F**	F	**T**	T	**T**	T	**T**
T	**F**	F	**F**	T	**F**	T	**T**
F	**T**	T	**T**	T	**T**	T	**F**
T	**T**	F	**F**	F	**F**	F	**F**
T	**F**	F	**T**	T	**T**	T	**F**
T	**F**	F	**F**	F	**F**	F	**F**
2		1		4		3	

Basics of modern logic: Gottlob Frege

- ***1879: Concept Script*** **("Begriffsschrift")**

  creates modern **predicate calculus**

  Examples:

  Father(Jaan,Mihkel).
  Father(Jaan,Ants).
  Father(Ants,Peeter).

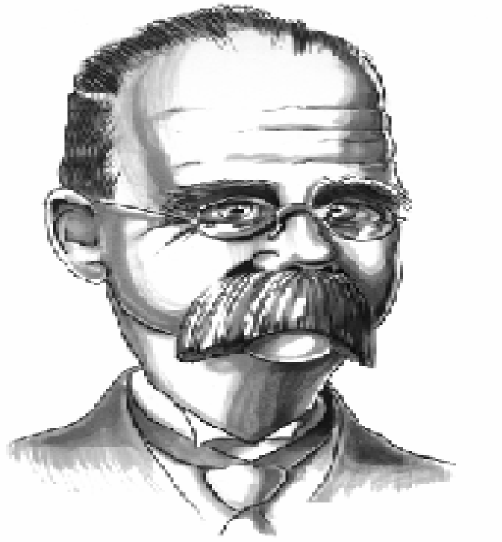
  For each x, y, z : Father(x,y) & Father(y,z) => Grandfather(x,z).

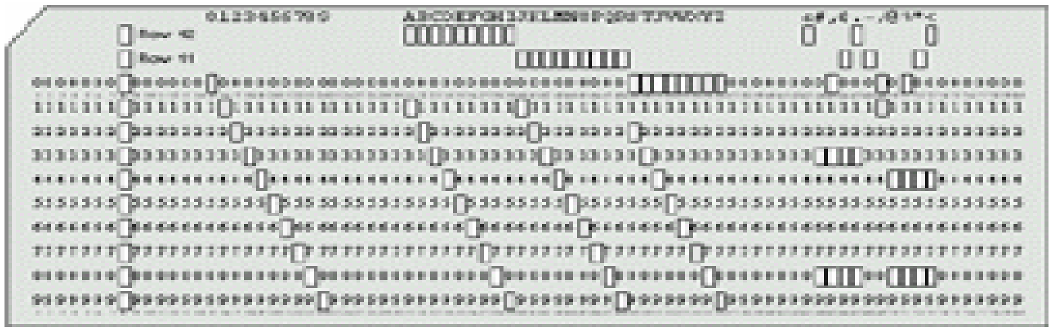
  Prove, that exist z, u so that Grandfather (z,u).

- **Frege as philosopher:** logicist
  a major advocate of the view that arithmetic is reducible to logic, a view known as logicism.

Hollerith's card

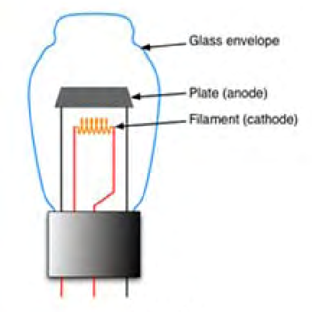
- **punch card, IBM card**
- **1890: Herman Hollerith:**
  USA census (processed in 2.5 years with punch cards
  (the 1880 census took 7 years)
- **Hollerith's company became IBM**
  - 1896 Tabulating Machine Company
  - 1911 his firm merged with two others
    => Computing Tabulating Recording (CTR)
    Corporation
  - it was renamed IBM in 1924



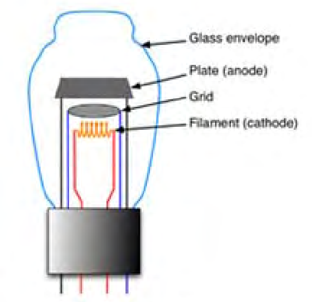


Vacuum tubes

- a device generally used to amplify, or otherwise modify, a signal by controlling the movement of electrons in an evacuated space
- 1900: vacuum diode
- Lee de Forest: 1906: vacuum triode



Diode



Triode

Set Theory: Georg Cantor

- 1845-1918
- founder of set theory
  - defined finite and infinite sets

- Detection of Paradoxes in set theory
- Basics of mathematics at once uncertain:
  it is not possible to take a "naïve”, or non-axiomatic, approach to set theory without risking contradiction

Russell & Whitehead

- **1910-1913: massive tracts on logic**

  Principia Mathematica
- **Paradox -> type theory**
- **Philosophical view: logicism**

Formalism; Hilbert

- **German mathematician and Logician: 1862-1943**
- **from the Philosophical aspect:** formalist
- **According to the formalist mathematics is:**
  - a game devoid of meaning in which one plays with symbols devoid of meaning according to formal rules which are agreed upon in advance.
  - therefore an autonomous activity of thought.
- “Hilbert’s program” **: Mathematics to be formulated on a solid and complete logical foundation:**
  - all of mathematics follows from a correctly-chosen finite system of axioms
  - that some such axiom system is provably consistent.

Intuitionism: Jan Brouwer & Arend Heyting

- intuitionism: an opponent of formalism.
- it is sometimes and rather simplistically characterized by refusing to use the law of excluded middle in mathematical reasoning.
- law of the excluded middle states that a proposition is either true or false.

Doesn't accept for example:

- A v –A (law of the excluded middle)
- - -A <=> A
- ((A => B) => A) => A

Formal system

- Tarski
  - produced axioms for logical consequence, and
  - worked on deductive systems,
  - the algebra of logic, and
  - the theory of definability.
  - model theoretic approach to semantics
- Carnap
  - learned much about Tarski's model theoretic approach to semantics.
  - indifference to metatheory;
  - fascination with formalized semantics;
- model theory
  - the study of the representation of mathematical concepts in terms of set theory, or
  - the study of the models which underlie mathematical systems.

Completeness and Incompleteness

- Kurt Gödel (1906-1978)
- 1930: the basic language of predicate calculus is complete
- 1931: formal arithemetics is not complete, you cannot describe it with a finite formal system
- for any computable axiomatic system that is powerful enough to describe arithmetic on the natural numbers then:
  1. The system cannot be both consistent and complete. (This is generally known as the incompleteness theorem.)
  2. The consistency of the axioms cannot be proved within the system.

Idea of the proof:

- The Liar Paradox, which goes back to ancient Greece, arises when a person stands up and says "I am lying."
  - If the person is lying, then the statement is true, so they are not lying; and
  - if they are not lying, the statement is false, so they are lying.
  - This is a seemingly inescapable paradox.
  - Gödel took a similar statement, "This statement is not provable," and showed how it could be formulated as a mathematical formula within arithmetic

Turing machine & Lambda-calculus of Church

- 1935-1937: article about Turing machine: universality, unsolvability
  - extremely basic symbol-manipulating devices, which can be adapted to simulate the logic of
  - any computer that could possibly be constructed.

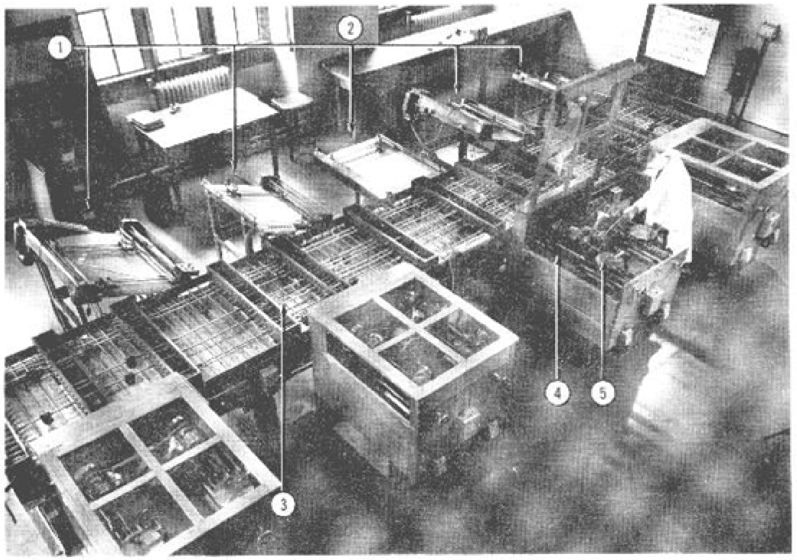
- 1936: Alonzo Church (1903-1955) lambda-calculus, Church's thesis.

  universality, unsolvability

  - Lambda calculus
    - the smallest universal programming language.
    - consists of a single transformation rule (variable substitution) and a single function definition scheme.
    - lambda calculus is universal: any computable function can be expressed and evaluated using this formalism.

Vannevar Bush

- **MIT: 1930-1935-1937: Differential Analyzer an analog computer that could solve differential equations with as many as 18 independent variables.**
- **Last version:**
  - weight 100 tons
  - 2000 vacuum tubes
  - 150 motors
  - thousands of relays



1 Input table
2 Output table
3 Shafts and gears used for interconnection
4 Torque amplifier
5 Integrator disk

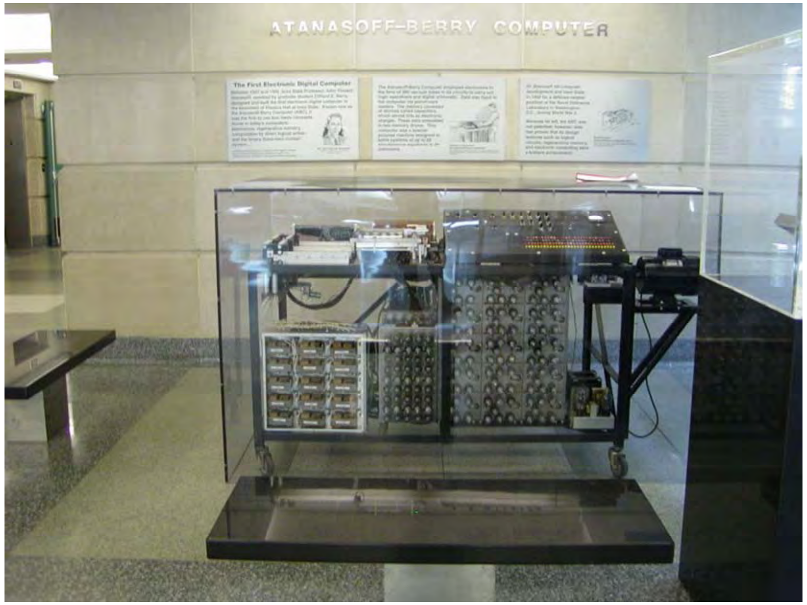
FIG. 4. The differential analyzer system, showing integrators, torque amplifiers, and shafting.

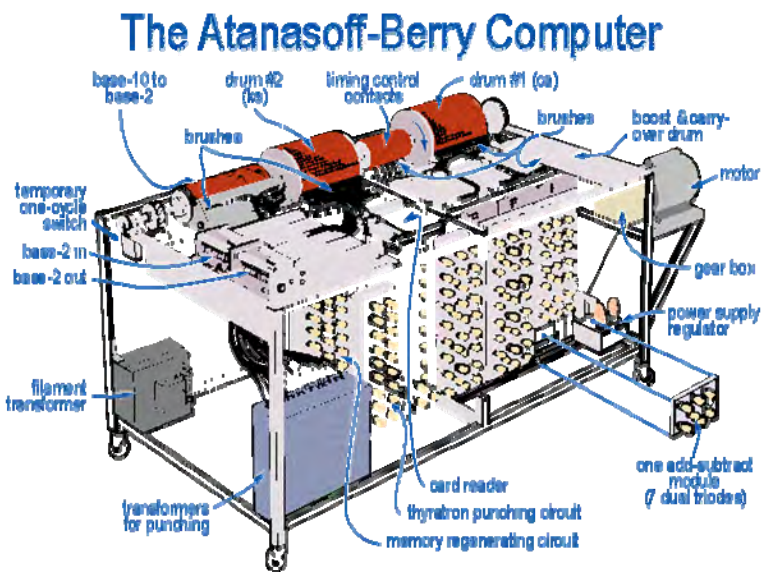
Claude Shannon (1916-2001)

- Offshoot of the Differential Analyzer work at MIT was the **birth of digital circuit design theory** by one of Bush's graduate students, Claude Shannon.
- MIT, 1938, Shannon’s Master’s Thesis
(A Symbolic Analysis of Relay and Switching Circuits)
“"possibly the most important, and also the most famous, master's thesis of the century" ”:
  - proved that Boolean algebra and binary arithmetic could be used **to simplify** the arrangement of the electromechanical relays then used in telephone routing switches
  - then turned the concept upside down and also proved that it should be possible to
use arrangements of relays
to solve Boolean algebra problems

Atanasoff's computer

- John Vincent Atanasoff (1903-1955)
- The Atanasoff-Berry Computer (ABC) was the first electronic digital computing device.
- The machine, conceived in 1937, was capable of solving up to 29 simultaneous linear equations and was successfully tested, though its input/output mechanism was still unreliable in 1942
- It was not a Turing complete computer
  (Turing complete: computational power capable of emulating a simplified model of a programmable computer known as the universal Turing machine)





Zuse's computer: Z3

- Konrad Zuse (1910-1995)
- first functional tape-stored-program-controlled computer, the Z3
  (in 1998 the Z3 was proven to be Turing-complete)
- first high-level programming language, the Plankalkül
- Z4, which became the first commercial computer (1946-1950)

Colossus vs Geheimfernschreiber

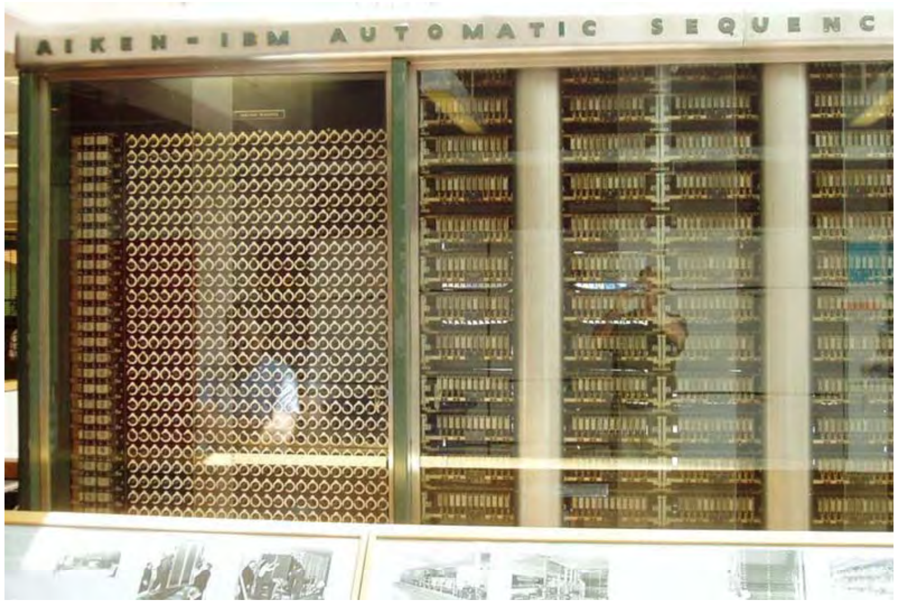
- The Colossus machines were early computing devices used by British codebreakers to read encrypted German messages during World War II.
  - not Turing-complete
    even though Alan Turing on whose research this definition was based, worked at Bletchley Park where Colossus was put into operation
- Geheimfernschreiber ("secret teleprinter"), aka
  T52 and
  Schlüsselfernschreibmaschine (SFM),
  codenamed Sturgeon by British cryptanalysts
  - a World War II German teleprinter cipher machine.

Mark I

- Howard Aiken (1900-1973)
  - devised the computer
  - At the dedication ceremony, Aiken failed to mention the involvement of IBM
    IBM was not pleased with this, and parted ways with Aiken.
- IBM's electric digital computer (Harvard) MARK I
  aka ASCC (Automatic Sequence Controlled Calculator)
  aka Aiken-IBM Automatic Sequence Controlled Calculator Mark I

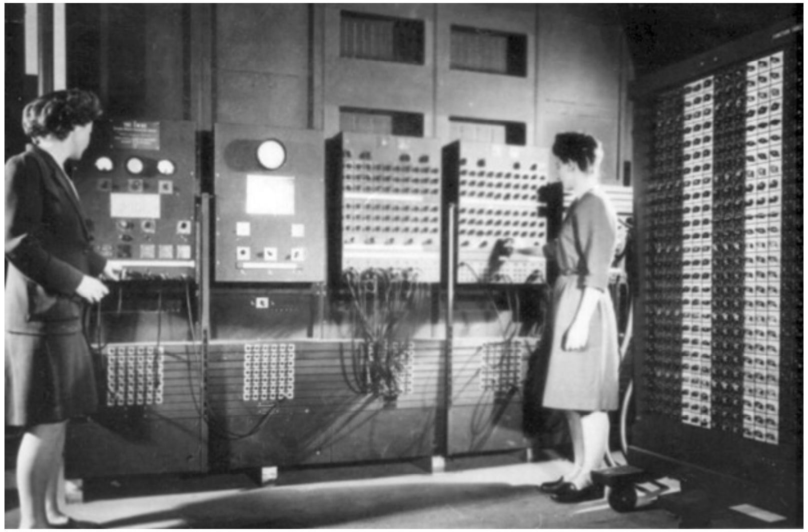
1939-1944

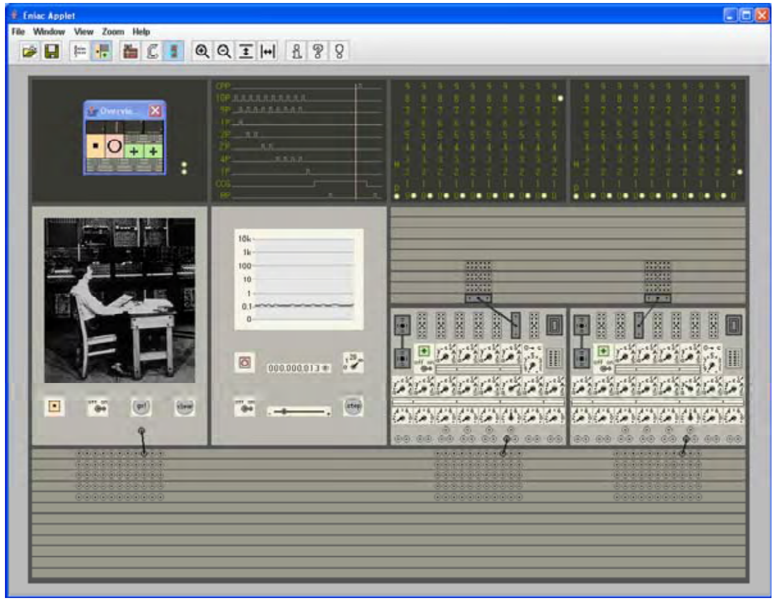
  - 750.000 components, 5 tons
  - could store 72 numbers, each 23 decimal digits long.
  - 3 additions or subtractions in a second.
  - multiplication took 6 seconds, a
  - division took 15.3 seconds
  - logarithm or a trigonometric function took over one minute.
  - read instructions from a punched paper tape
  - A loop was accomplished by joining the end of the paper tape containing the program back to the beginning of the tape (literally creating a loop).
- Mark IV all-electronic



Eniac

- ENIAC, short for Electronic Numerical Integrator and Computer
- was the first
(there was a controversy about this)
  - large-scale,
  - electronic,
  - digital computer
  - reprogrammable
    - the first problems run on the ENIAC were related to the design of the hydrogen bomb.
- Eniac Java Simulation
http://www.zib.de/zuse/Inhalt/Programme/Eniac/eniac.html





Comparison of early computers

Defining characteristics of five first operative digital computers

Computer	Nation	Year	Digital	Binary	Electronic	Programmable	Turing complete
Atanasoff-Berry Computer	USA	1937–42	Yes	Yes	Yes	No	No
Zuse Z3	Germany	1941	Yes	Yes	No	Fully, by paper tape	Yes
Colossus computer	UK	1944	Yes	Yes	Yes	Partially, by rewiring	No
Harvard Mark I/IBM ASCC	USA	1944	Yes	No	No	By paper tape	Yes
ENIAC	USA	1946	Yes	No	Yes	Partially, by rewiring	Yes